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Pre-Participation Screening of Young Competitive Athletes for Prevention of Sudden Cardiac Death

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In 1982 a nationwide program of pre-participation screening including 12-lead electrocardiography (ECG) was launched in Italy. The aim of this article is to examine whether this 25-year screening program should be considered a valid and advisable public health strategy. The analysis of data coming from the long-running Italian experience indicates that ECG screening has provided adequate sensitivity and specificity for detection of potentially lethal cardiomyopathy or arrhythmias and has led to substantial reduction of mortality of young competitive athletes by approximately 90%. Screening was feasible thanks to the Italian Health System, which is developed in terms of health care and prevention services, and because of the limited costs of cardiovascular evaluation in the setting of a mass program. On the basis of current scientific evidence the implementation of a mass-screening program aimed to prevent athletic-field sudden cardiac death should be at least carefully considered by public health administrators worldwide. (J Am Coll Cardiol 2008;52:1981–9) © 2008 by the American College of Cardiology Foundation

"He who saves a single life saves the whole world."
—Talmud Sanhedrin 4:5 (1)

Sudden death during sports is often the first and definitive manifestation of an underlying cardiovascular disease, which usually has a silent clinical course (2–6). Medical evaluation before competition offers the potential to detect still asymptomatic athletes with life-threatening heart diseases and to protect them from sudden cardiac death (SCD). A nationwide program of pre-participation screening of young competitive athletes (YCAs), essentially based on 12-lead electrocardiography (ECG), was launched in Italy in 1982 (7) (Fig. 1). The aim of this viewpoint article is to examine the reasons why this 25-year screening program should be considered a valid and advisable public health strategy.

Is SCD in the athlete a serious health problem? Cardiovascular fatalities during sports are rare; however, the public health relevance of a disease/event is not necessarily linked to its high occurrence (8). The sudden and unexpected death of a YCA is always a powerful and tragic event that devastates families, other competitors, institutions (high school, college, or professional organization), sports medicine team, and the community. The sudden demise of a YCA has a tremendous impact on the media, because it affects young and apparently healthy individuals who are regarded as the healthiest group in society and often as heroes. Instinctively, everyone wonders what intervention might have prevented the death.

Incidence rates. The risk of SCD in athletes increases with age and is greater in male subjects. The incidence of SCD among U.S. high-school and college athletes (age range 12 to 24 years) has been estimated to be <1 in 100,000 participants/year (4,5), whereas a prospective study in Italy reported a yearly incidence of approximately 3 of 100,000 athletes (age range 12 to 35 years) (6). This discrepancy is explained by differences in age and gender of the 2 athletic populations, with the U.S. athletes carrying a substantially lower risk because of younger age and inclusion of more female subjects.

Relative risk. Athletic participation carries an inherent risk of SCD (6,9). Adolescent and young adults involved in a sports activity have an estimated risk of SCD 2.8 times greater than that of their nonathletic counterparts (6). It is the combination of physical exercise and underlying cardiovascular disorders rather than exercise alone that triggers athletic-field arrhythmic cardiac arrest. This finding reinforces the concept that physicians and athletic trainers should ensure that athletes are systematically screened to identify those with potentially lethal heart diseases and to protect them against the increased risk of SCD.

Causes of sudden death. The primary purpose of pre-participation screening is to identify the cohort of ath-

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Abbreviations and Acronyms

ARVC/D = arrhythmogenic right ventricular cardiomyopathy/dysplasia
HCM = hypertrophic cardiomyopathy
SCD = sudden cardiac death
YCA = young competitive athlete

letes affected by cardiovascular diseases at risk of SCD during sports. A broad range of conditions, including congenital and inherited heart disorders, have been reported to provoke SCD in young athletes (2–6,9–13). Cardiomyopathies have been consistently implicated as the primary cause of sports-related cardiac arrest in YCAs, with hypertrophic cardiomyopathy (HCM) accounting for one-third of fatal cases in the U.S. (4,5,11) and arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) accounting for approximately one-fourth in Italy (2,3,6,13).

Systematic monitoring of fatalities among the young population (age ≤35 years) of the Veneto region of Italy has shown that HCM rarely underlies SCD in YCAs, whereas it is one of the leading causes of death among the nonathletic population of the same age range (2,6). This selective reduction of SCD from HCM in Italian athletes cannot be ascribed to ethnic and geographic differences in the disease prevalence. Comparison between Italian findings and those reported by Burke et al. (11) in the U.S. shows a similar prevalence of HCM as a cause of nonsports-related SCD. Rather, the discrepancy might be reasonably explained by the unique exposure of the Italian athletic population to systematic cardiovascular screening leading to identification and reduction of the SCD risk of athletes with HCM (2,3,14). As a consequence, other cardiovascular conditions such as ARVC/D, premature coronary artery disease, and congenital coronary anomalies have thereby come to account for a greater proportion of all SCD in Italian athletes. Arrhythmogenic right ventricular cardiomyopathy/dysplasia is a worldwide increasingly recognized cause of morbidity and mortality, mostly in young individuals and athletes (15–17). In the past, the misconception that ARVC/D was a Venetian disease relied on the unawareness of its clinical and pathologic features in other countries, where it remained largely underdiagnosed by clinicians and pathologists for a long time (18).

Is an ECG an Accurate Test for Early Detection of Athletes With At-Risk Cardiovascular Diseases?

Ideally, an efficient pre-participation screening test should miss very few individuals with at-risk cardiovascular diseases, although a proportion of false positive results can be accepted (8).

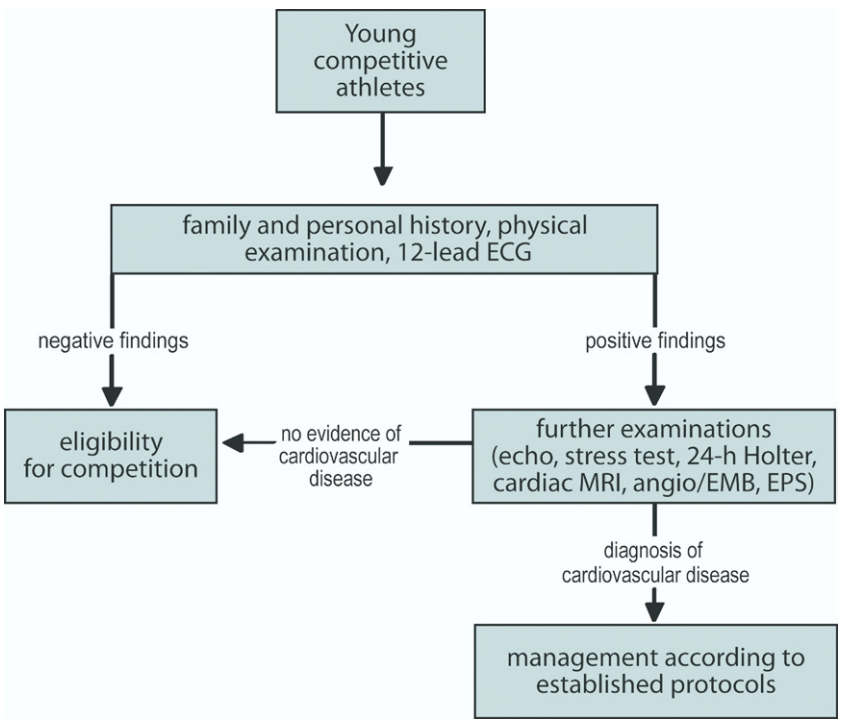

Figure 1 Flow Chart of the Italian Protocol of Cardiovascular Pre-Participation Screening

Young competitive athletes are defined as individuals 12 to 35 years of age who are engaged in a regular fashion in exercise training as well as participating in official athletic competitions. First-line examination includes family history, physical examination, and 12-lead electrocardiography (ECG); additional tests are requested only for subjects who have positive findings at the initial evaluation. Angio/EMB = contrast angiography/endomyocardial biopsy; EPS = electrophysiologic study with programmed ventricular stimulation; MRI = magnetic resonance imaging. Reprinted, with permission, from Corrado et al. (3).

Screening sensitivity. Most cardiovascular conditions responsible for SCD in YCAs are clinically silent and unlikely to be suspected or diagnosed on the basis of spontaneous symptoms (2–6,9–13). This explains why a screening protocol based solely on the athlete's history and physical examination is of marginal value for identification of athletes at risk for SCD (19). The Italian screening program has shown that ECG, in addition to history and physical examination, has a substantial incremental value for identifying asymptomatic athletes who have potentially lethal heart disorders and might be as sensitive as echocardiographic examination. Among 33,735 athletes undergoing pre-participation screening at the Center for Sport Medicine in Padua, 3,016 (8.9%) were referred for additional testing, mainly echocardiography, and 621 were disqualified for cardiovascular reasons (1.8%) (2). Of 22 athletes (all asymptomatic) with a clinical and echocardiographic diagnosis of HCM, 18 (82%) showed 1 or more ECG abnormalities at pre-participation evaluation and 5 (23%) had premature ventricular beats. Conversely, only 5 athletes (23%) had a family history or a cardiac murmur or both.

An absolute value of screening sensitivity for HCM could not be derived from these data, because systematic echocardiographic findings were not available. However, the 0.07% prevalence of HCM found in YCAs of the Veneto region of Italy, evaluated by ECG screening, was similar to the 0.10% prevalence reported for young white individuals in the U.S., assessed by echocardiography (20).

Other ECG-detectable diseases responsible for SCD include ARVC/D, dilated cardiomyopathy, Wolff-Parkinson-White syndrome, and ion channel diseases such as Lènegre conduction disease, long and short-QT syndromes, and Brugada syndrome (Table 1). Overall, these conditions (including HCM) account for approximately two-thirds of fatal events in YCAs, on the basis of published series from the U.S. and Italy (3).

In contrast, the possibility of detecting either premature coronary atherosclerosis or anomalous coronary artery in YCAs is limited by the scarcity of baseline ECG signs of myocardial ischemia (2,3). Although additional exercise testing might enhance the potential to discover ischemic conditions, its systematic use is limited by the low test sensitivity/specificity for coronary artery diseases (including congenital coronary arteries) in the general population of YCAs.

Screening specificity. A screening test is not intended to be diagnostic; it separates apparently well persons who probably have a disease from those who probably do not. Persons with positive or suspicious findings will be subsequently referred for further clinical evaluation to achieve a definitive diagnosis.

An ECG has been traditionally considered to be a nonspecific and noncost-effective screening tool in the athletic population, because of its presumed high level of false positive results (19). This has been the result of the concept that physiologic ECG changes, which usually occur in trained athletes as an expression of heart adaptation to sustained physical exercise, overlap significantly with pathologic ECG abnormalities seen in the cardiovascular diseases that cause SCD (19,21,22). The Italian experience has disproved this general idea that ECG is a nonspecific screening test. Among 42,386 athletes initially screened by history, physical examination, and ECG, the percentage of false positives (i.e., athletes with a normal heart but positive screening findings) requiring additional testing, mainly echocardiography, did not exceed 9% (23).

ECG interpretation. Italian sports physicians who have a specific training, scientific background, and medical skill for appropriate interpretation of an athlete's ECG played a crucial role for achieving such an adequate accuracy of first line cardiovascular screening (3,22). Such physicians attend postgraduate residency training programs in sports medicine (and sports cardiology) full-time for 4 years and work in sports medical centers, either public or private, specifically devoted to periodical screening of athletes.

Misinterpretation of ECG by inexperienced physicians might lead to serious medical consequences and reduce cost-utility of the screening process (22). Athletes might undergo an expensive diagnostic work-up or might be unnecessarily disqualified from competition for abnormalities, such as isolated voltage criteria for left ventricular hypertrophy, that fall within the normal range for athletes. Conversely, signs of potentially lethal organic heart disease, such as T-wave inversion, might be misinterpreted as normal variants of an athlete's ECG. Appropriate interpretation of an athlete's ECG requires the distinction of 2 main groups of abnormalities on the basis of their prevalence, relation to exercise training, inherent cardiovascular risk, and need for further clinical investigation to confirm (or exclude) an underlying cardiovascular disease (Fig. 2). According to the long-term Italian experience, limitation of further expensive diagnostic work-up to the fewer athletes showing Group 2 ECG changes results in a considerable cost-saving and improvement of screening cost-effectiveness (22).

Is There an Effective Treatment for Athletes Diagnosed With Heart Diseases at an Early Stage?

The importance of identification by ECG screening of asymptomatic athletes with cardiovascular diseases relies on the concrete possibility of SCD prevention by lifestyle modification, including restriction of competitive sports activity and concomitant prophylactic treatment by antiarrhythmic drugs, beta-blocker drugs, and implantable cardioverter-defibrillator therapy. Athletes who did not obtain eligibility for competition because of cardiovascular reasons were found to have a good long-term clinical course (2). In particular, none of the 22 asymptomatic athletes who were disqualified for HCM died during a 7.8-year follow-up period (2). Of note, 3 of these former athletes with HCM afterwards experienced serious arrhythmic complications that were suc-

Table 1 ECG Features of Cardiac Diseases Detectable at Pre-Participation Screening in Young Competitive Athletes

Disease	QTc Interval	P-Wave	PR Interval	QRS Complex	ST-Segment Interval	T-Wave	Arrhythmias
Hypertrophic cardiomyopathy	Normal	(Left atrial enlargement)	Normal	Increased voltages in mid-left pre-cordial leads; abnormal "q" waves* in inferior and/or lateral leads; (LAD, LBBB); (delta wave)	Down-sloping (up-sloping)	Inverted in mid-left pre-cordial leads; (giant and negative in the "apical" variant)	(Atrial fibrillation); (PVB); (VT)
Arrhythmogenic right ventricular cardiomyopathy/ dysplasia	Normal	Normal	Normal	Prolonged >110 ms in right pre-cordial leads; epsilon wave in right pre-cordial leads; reduced voltages ≤0.5 mV in frontal leads; (RBBB)	(Up-sloping in right pre-cordial leads)	Inverted in right pre-cordial leads	PVB with an LBBB pattern; (VT with an LBBB pattern)
Dilated cardiomyopathy	Normal	(Left atrial enlargement)	(Prolonged ≥0.21 s)	LBBB	Down-sloping (up-sloping)	Inverted in inferior and/or lateral leads	PVB; (VT)
Myocarditis	(Prolonged)	Normal	Prolonged ≥0.21 s	(Abnormal "q" waves)*	Down- or up-sloping	Inverted in ≥2 leads	(Atrial arrhythmias); (PVB); (2nd or 3rd degree AV block); (VT)
Long-QT syndrome	Prolonged >440 ms in male subjects, >460 ms in female subjects	Normal	Normal	Normal	Normal	Bifid or biphasic in all leads	(PVB); (torsades de pointes)
Brugada syndrome	Normal		Prolonged ≥0.21 s	S1S2S3 pattern; (RBBB/LAD)	Up-sloping "coved-type" in right pre-cordial leads	Inverted in right pre-cordial leads	(Polymorphic VT); (atrial fibrillation) (sinus bradycardia)
Lenègre disease	Normal	Normal	Prolonged ≥0.21 s	RBBB; RBBB/LAD; LBBB	Normal	Secondary changes	(2nd or 3rd degree AV block)
Short-QT syndrome	Shortened <300 ms	Normal	Normal	Normal	Normal	Normal	Atrial fibrillation (polymorphic VT);
Pre-excitation syndrome (WPW)	Normal	Normal	Shortened <0.12 s	Delta wave	Secondary hanges	Secondary changes	Supraventricular tachycardia; (atrial fibrillation)
Coronary artery diseases†	(Prolonged)	Normal	Normal	(Abnormal "q" waves)*	(Down- or up-sloping)	Inverted in ≥2 leads	PVB; (VT)

Less common or uncommon electrocardiography (ECG) findings are reported in parentheses. *Abnormal "q" waves ≥0.04 s in duration or ≥25% of the height of the ensuing R-wave or QS pattern in 2 or more leads; †coronary artery diseases = either premature coronary atherosclerosis or congenital coronary anomalies. Modified from Corrado et al. (3).

AV = atrioventricular; LAD = left axis deviation of −30° or more; LBBB = left bundle branch block; RBBB = right bundle branch block; PVB = either single or coupled premature ventricular beats; QTc = QT interval corrected for heart rate by Bazett's formula; VT = either nonsustained or sustained ventricular tachycardia; WPW = Wolff-Parkinson-White.

cessfully treated by beta-blocker drugs and/or amiodarone. Therefore, the favorable long-term outcome was the result of both disqualification from competitive sports and the subsequent close follow-up and clinical management.

Does Pre-Symptomatic Identification of Athletes With Cardiovascular Diseases Reduce Mortality?

The final objective of screening athletes for cardiovascular diseases is to prevent SCD during sports. A time-trend analysis of the incidence of SCD in YCAs in the Veneto region of Italy over 26 years (1979 to 2004) demonstrated a sharp decline of mortality rates after the introduction of the nationwide screening program (23). The annual incidence of SCD in athletes decreased by 89%, from 3.6/100,000 athlete/years in the pre-screening period (1979 to 1981) to 0.4/100,000 athlete-years in the late-screening period (1993 to 2004) (Fig. 3). By comparison, the incidence of SCD in the unscreened nonathletic population of the same age did not change significantly over that time. The decline in death rate started after mandatory screening was launched and persisted to the late screening period. Most of the reduced death rate was due to fewer cases of SCD from cardiomyopathies. A parallel study of eligibility for competitive sports showed that the proportion of athletes identified and disqualified because of cardiomyopathies (mostly HCM and ARVC/D) doubled from the early to the late screening period. This substantiates the concept that the decrease of mortality from cardiomyopathy was the result of increasing identification over time of affected athletes at pre-participation screening.

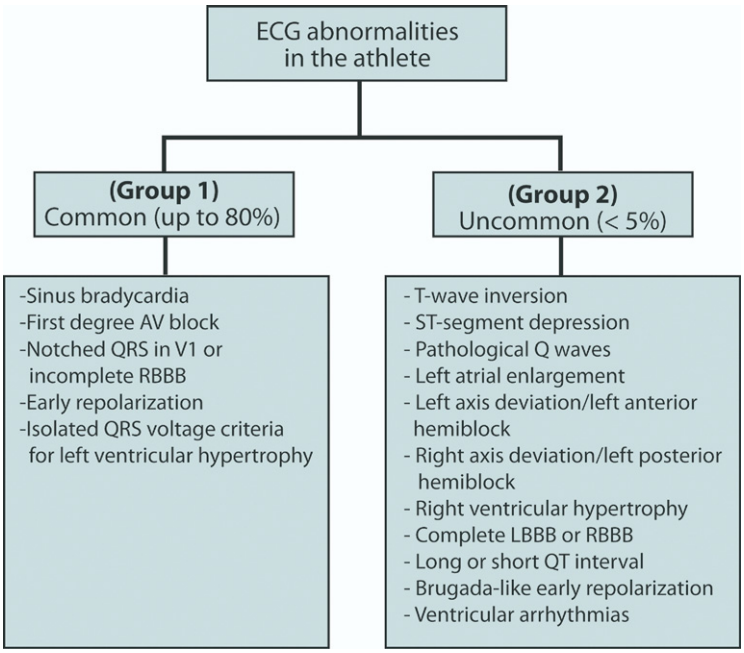

Figure 2 **Classification of ECG Abnormalities in the Athlete**

Common electrocardiography (ECG) abnormalities: up to 80% of trained athletes exhibit ECG changes such as sinus bradycardia, first degree atrioventricular (AV) block, early repolarization, incomplete right bundle branch block (RBBB) and pure increase of QRS voltages (Group 1). Such common ECG changes are the consequence of the physiologic cardiovascular adaptation to sustained physical exertion and do not reflect the presence of an underlying cardiovascular disease. Therefore, they are not associated with an increase of cardiovascular risk and allow eligibility to competitive sports without additional evaluation. Uncommon ECG abnormalities: this subset includes uncommon ECG patterns (<5%) such as ST-segment and T-wave repolarization abnormalities, pathological Q waves, intraventricular conduction defects, and ventricular arrhythmias (Group 2). These ECG abnormalities are unrelated to athletic conditioning and should be regarded as an expression of possible underlying cardiovascular disorders, notably cardiomyopathies and cardiac ion channel diseases, and thus associated with an inherent increased risk of sudden arrhythmic death. Modified from Corrado et al. (22). LBBB = left bundle branch block.

Critical Appraisal

These data showing the substantial reduction of mortality among Italian athletes after screening implementation have raised a number of criticisms.

Study design. Thompson and Levine (24) stressed that the Italian study was not a controlled comparison of screening versus nonscreening of YCAs but an observational population-based investigation.

The study was not a randomized trial, and unequivocal conclusions that the reduced mortality was solely the consequence of the screening process cannot be drawn. However, the strong cause-effect relationship between implementation of the screening program and the substantial reduction (by 89%) of SCD in Italian athletes should remove all doubt of the efficacy of screening to identify athletes with at-risk cardiovascular conditions and its ability to save lives. The study (23) showed that: 1) there was a coincident timing between decline of SCD in YCAs and screening implementation in Italy; 2) most of the reduced incidence of SCD was due to fewer deaths from cardiomyopathies, and it was accompanied by the concomitant increase of the proportion of YCAs with cardiomyopathies who were identified and disqualified from competition at the Center for Sports Medicine in Padua during the same time interval; and 3) during the study period, the incidence of SCD did not change among the unscreened nonathletic population of the Veneto region of the same age range.

Mortality rates. It has been argued that the annual death rate of Italian competitive athletes before mandatory screening was higher and the late-screening annual death rate was roughly similar to that reported by the National Center for Catastrophic Sport Injury Research (NCCSIR) in U.S. high-school and college athletes (5,24). It has been thus suggested that no screening process or less formal screening process practiced in the U.S. might have been as effective as the Italian program. However, the 2 athletic populations were noncomparable with regard to gender and age, so that the differences in mortality rates are explained by the recognized greater risk of SCD in male and older athletes (5,6). According to the NCCSIR estimates, the overall rate of SCD among U.S. high-school and college participants was 5-fold higher for male than for female athletes (0.75/100,000 athletes/year vs. 0.13/100,000 athletes/year). Male college athletes (age range 20 to 24 years) had twice the estimated death rate of their high-school (age range 12 to 19 years) counterparts (1.45/100,000 athletes/year vs. 0.66/

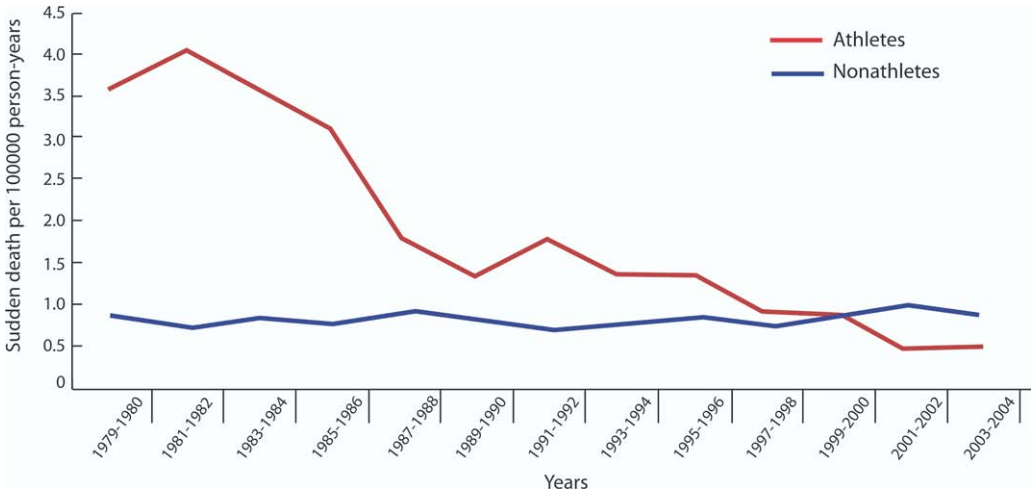

Figure 3 **Annual Incidence Rates of Sudden Cardiac Death Among Screened Competitive Athletes and Unscreened Nonathletes in the Veneto Region of Italy From 1979 to 2004**

Modified from Corrado et al. (23).

100,000 athletes/year) (5). The mortality rate of the Italian athletic population was expectedly higher (approximately 3.60/100,000 athletes during the pre-screening era), because it included predominantly male (82%) and older (age range 12 to 35 years) athletes (6).

Data accuracy and denominators. Whereas the Italian data were systematically gathered from a well-defined geographic area (the Veneto region of Italy) according to a prospective study design, the U.S. SCD rates were mostly based on retrospective analysis of data collected by the NCCSIR, new accounts, informal communications, and reports (4,5). Although these sources of information were the best available in the U.S., reasonable concerns exist regarding their reliability for estimation of an athlete's SCD rate due to unavoidable limitations inherent in the data collection and the retrospective study design. As recognized by Van Camp et al. (5), all SCDs in athletes occurring in the U.S. were unlikely to have been reported by the NCCSIR, leading to an incorrectly low number of events and underestimation of mortality rates. The accuracy of the determination of incidence rates of SCD among U.S. athletes is questionable, because denominator data did not reflect the real number of active athletes in each year but rather the total participation figures divided by an estimate of the average number of sports in which each high-school and college athlete participated.

Other factors. The alternative hypothesis—that Italian general doctors not involved in the screening process might have detected more individuals with cardiomyopathy over time, thus removing potential victims from the athletic pool—can not be completely excluded, although it is purely speculative (24). What the Italian screening data undeniably demonstrated, instead, is that reduction in athlete mortality paralleled the increasing number of athletes with cardiomyopathies (both HCM and ARVC/D) who were identified and disqualified at pre-participation screening over the study period (23).

Alternative Preventive Strategies

There are not competing public health strategies either more efficient or cost-effective than ECG screening for prevention of SCD in the athlete.

Pre-participation cardiovascular screening has traditionally been performed in the U.S. by means of history (personal and family) and physical examination, without 12-lead ECG or other testing. This screening method is currently recommended by the American Heart Association, although it has a recognized limited power to detect potentially lethal cardiovascular abnormalities in young athletes (19). Glover and Maron (25) found that, of 134 high-school and collegiate athletes experiencing SCD who had undergone a pre-participation medical evaluation by history and physical examination, only 3% were suspected of having cardiac disease and eventually <1% received an accurate diagnosis. The Italian screening program has shown that ECG makes the difference. Among 22 athletes with HCM who were detected by ECG screening at the Center for Sport Medicine in Padua and disqualified from competition, only 5 (23%) would had been identified on the basis of a positive family history, symptoms, or abnormal physical findings, in the absence of an ECG (2).

The presence of a free-standing, automated external defibrillator at sporting events might be a valuable back-up for conditions unrecognized by ECG screening such as coronary artery diseases, either atherosclerotic or congenital, but should be considered neither a substitute for pre-participation evaluation nor a justification for participation

in competitive sports of athletes with at-risk heart diseases. Chances for on-field successful resuscitation are remote, even if cardiopulmonary resuscitation is started immediately and defibrillation equipment is readily available. Drezner and Rogers (26) reported that only 11% of athletes with underlying cardiomyopathy survived from athletic-field cardiac arrest, despite a witnessed collapse, timely cardiopulmonary resuscitation, and prompt defibrillation.

Cost-Benefit Considerations

Screening of large athletic populations has a significant socioeconomic impact. How pre-participation screening might be generalizable to other countries is a complex issue that goes beyond the scope of the present review article. Strategies for implementing the screening program depend on the particular socioeconomic and cultural background as well as on the specific medical systems in place in different countries. In Italy screening is made feasible thanks to the National Health System, which is developed in terms of health care and prevention services, and to the limited costs of cardiovascular evaluation in the setting of a mass program (3). The cost of performing a pre-participation cardiac history, physical examination, and ECG by qualified physicians has been estimated to be ≈€30/athlete (≈$45 U.S.). The screening cost is covered by the athlete or by the athletic team, except for athletes younger than age 18 years, for whom the expense is supported by the National Health System. Moreover, the cost of further evaluation of athletes with positive findings at first-line examination is smaller than expected on the basis of the presumed low specificity of the athlete's ECG. The percentage of athletes requiring additional testing, mainly echocardiography, has been found to be ≈9%, with a modest proportional impact on cost (2,23).

Costs of infrastructure and training courses for pre-participation screening must also be taken into account in the calculation of the overall screening cost (3). Strategies for screening implementation should be in the hands of health care policymakers and service providers, with their program development based on the specific national health and socioeconomic systems (27).

The young age of the screened athletic population and the genetic nature of the causes of SCD in this age group profoundly impacts cost-benefit considerations. Unlike older patients with coronary artery disease or heart failure, adolescents and young adults diagnosed with a genetic disease at risk of arrhythmic SCD will survive for many decades with normal or nearly normal life expectancy, thanks to restriction from competition and prophylactic therapy against life-threatening arrhythmias. This large number of life-years saved influences cost-effectiveness analysis and explains why all reports on ECG screening of young individuals have provided cost estimates/year of life saved well below $50,000, which is the traditional threshold to consider a health intervention cost-effective (27–30). The benefit of pre-participation evaluation goes beyond the detection of index athletes with an inherited heart disease, because it enables cascade screening of relatives and results

Table 2 Pre-Participation Athletic Screening in Other European Countries

Country	Medical/Sports Associations	Target Athletic Population	Screening Protocol
Luxembourg	National Sports Ministry, Olympic Medical Committee, National Association of Sports Physicians	Competitive athletes of all sports	History, physical examination, ECG (required)
Sweden	National Board of Health and Welfare, National Federations of Sports	Elite athletes of all sports	History, physical examination, ECG (recommended)
Norway	Norwegian Football Association Medical Committee	Professional football athletes	History, physical examination, ECG, echocardiography (required)
Germany	German Association of Sports Medicine, National Sports Federations	Professional athletes of all sports	History, physical examination, ECG, echocardiography, exercise testing (required)
Poland	Ministry of Sports and Tourism, Ministry of Health, Polish Cardiac Society, Sports Federations	Competitive athletes (age <23 yrs) of all sports and national team members	History, physical examination, ECG (required)
France	National Sports Ministry	Professional athletes of all sports	History, physical examination, ECG, echocardiography, exercise testing (required)
	French Society of Cardiology	Competitive athletes of all sports	History, physical examination, ECG (recommended)
Scotland	Government Department of Health	Competitive football athletes (age 16 yrs)	History, physical examination, ECG (required)
England	British Lawn Tennis and Football Associations	Competitive athletes	History, physical examination, ECG (required)
Greece	Hellenic College of Sports Medicine, National Sports Federations	Competitive athletes of all sports	History, physical examination, ECG (recommended)
Belgium	National Sports Federations	Athletes of cycling and motocross sports	History, physical examination, ECG (required)
Spain	High Sports Government Council	Competitive athletes of all sports	History, physical examination, ECG (recommended)
The Netherlands	Working group of Cardiovascular Prevention and Rehabilitation, National Olympic Committee, National Sports Federations, Netherlands Society of Cardiology	Competitive athletes of all sports Elite athletes of cycling, motor and flying sports, and diving	History, physical examination, ECG (recommended) History, physical examination, ECG (required)

ECG = electrocardiography; competitive athletes = athletes engaged in a regular fashion in exercise training and participating in official athletic competitions as an organized team or individual sport event; elite athletes = athletes of I and II leagues; professional athletes = elite athletes engaged in athletic activities with a labor contract.

in a multiplier effect for identifying other affected family members and saving additional lives.

Disqualification From Competitive Sports

Athlete disqualification might be associated with an important individual cost in terms of health, contentment, and even future opportunity for professional sports. However, the risk of SCD associated with competitive sports in the setting of life-threatening cardiovascular disease is a controllable risk factor, and the devastating impact of even infrequent fatal events in the young athletic population justifies appropriate restriction from competition (31). Thanks to the long-running Italian experience, we have learned the lesson that screening athletes for cardiomyopathies and arrhythmias is most productive in preventing athletic-field SCD, whereas the exclusion from competition of many other young athletes with nonlethal diseases is more arbitrary and not as productive. The prevalence of Italian athletes who were diagnosed and disqualified because of cardiovascular diseases was approximately 2%; however, true potentially lethal conditions such as cardiomyopathies, rhythm and conduction disturbances, long-QT syndrome, valvular heart disease (predominantly aortic valve stenosis), premature coronary artery disease, and Marfan syndrome were identified in a smaller subgroup not exceeding 0.2% (23). This has significant implications for optimizing sports eligibility guidelines and management of YCAs with cardiovascular diseases in the future. The main objective should be to reduce the number of unnecessary disqualifications and to adapt (rather than restrict) sports activity in relation to the specific cardiovascular risk.

Conclusions

Pre-participation cardiovascular evaluation of competitive athletes essentially based on ECG seems, according to the long-term Italian experience, to be a lifesaving strategy that adequately meets the criteria for a good screening program (8): 1) the risk of SCD during sports represent a serious health problem; 2) ECG screening allows identification of still-asymptomatic athletes with at-risk cardiovascular diseases; 3) an effective management strategy exists on the basis of restriction of life-threatening training/competition and subsequent clinical treatment; and most importantly, 4) early detection and management of athletes favorably modifies the outcome of the underlying disease and leads to reduction of SCD.

It is noteworthy that a 25-year interval was required to generate these Italian results. Until other studies, either observational or randomized, on athletic populations of comparable size and follow-up are conducted, the existing data provide good evidence that ECG screening decreases the risk of SCD in athletes. Accordingly, pre-participation ECG screening is currently recommended by the International Olympic Committee ("Lausanne Recommendations") (32) as well as by most European Cardiologic Societies and Sports Medical Federations (Table 2). However, major obstacles for a definitive screening launch still exist and rely on the lack of national legislation. Thanks to the continuous and cooperative efforts of Medical Societies and Sports Organizations, the hope is that in the near future public health care policymakers will actually consider implementation of such a screening program aimed to reduce the number of preventable athletic-field SCDs.

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